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SUMMARY - Factors affecting NSP digestibility on poultry diets are reviewed. The variation of plant NSP type and its content are followed by consideration of the effects of NSP on digestibility and overall nutrient digestion. Finally, effects of supplementation with exogenous NSP enzymes are shown in relation to diet composition plus effects of feed processing and animal physiology.

Key words: Cereals, digestibility, NSP, poultry.

RESUME - *"Facteurs affectant la digestibilité des polysacharides non-amylacés chez les volailles". Les facteurs qui affectent la digestibilité des polysaccharides non amylacés (PNA) dans les régimes pour volailles sont passés en revue. La variation du type de PNA végétaux ainsi que leur teneur, est suivie par la prise en compte des effets des PNA sur la digestibilité et la digestion globale des nutriments. Finalement, les effets de la supplémentation avec des enzymes exogènes de PNA sont montrés en relation avec la composition du régime plus les effets de la transformation des aliments et la physiologie animale.*

Mots-clés : *Céréales, digestibilité, polysaccharides non amylacés, volailles.*

Introduction

Polysaccharides are major components of plant materials used in rations for monogastrics. They are macromolecular polymers of monosaccharides linked by glycosidic bonds. The most important, starch, shows glucose units linked by α-(1-4) with a few α-(1-6) bonds and 90-95% of starch is digested in the small intestine of poultry through endogenous enzyme activity. Non-starch polysaccharides (NSP) include celluloses, hemicelluloses, pectines and oligosaccharides (α-galactosides, etc.). They can also be divided into water-soluble and water-insoluble fractions; fractions which have greater relevance to their nutritional values. Birds do not possess endogenous enzymes capable of cleaving and digesting the ß(α) linked NSP. The water-insoluble NSP can be considered practically undigested by poultry and only soluble NSP has the potential to be digested by birds (Carré, 1993). However, soluble NSP are known to posses anti-nutritional properties by either encapsulating nutrients and/or depressing overall nutrient digestibility through gastro-intestinal modifications. The depression in digestion of nutrients results in a decrease of the AME of the diet with a concurrent increase of the feed conversion ratio (FCR).

The objective of the present paper is to review a number of factors affecting NSP digestibility. The variation of plant-NSP type and content will be considered followed by consideration of the effects of NSP on digestibility and overall nutrient digestion. Finally consideration will be given to the effects of supplementation with exogenous NSP-enzymes in relation to diet composition plus effects of feed processing and animal physiology.

Variability in plant NSP and its consequence on their digestibility

Recent reports have suggested that the NSP content of plants varies not only in accordance to the plant species but also varies between genotype or cultivar of the same species. Furthermore the agronomic cultivation conditions such as environmental factors prior to harvest and storage conditions after harvest can influence NSP content.

The NSP may be relatively simple such as the cereal ß-D-glucans which are linear polymers of glucose with ß-(1-3),(1-4) glycosidic links. The other major cereal polysaccharides, the arabinoxylans, are more complex being composed of two sugars, arabinose and xylose, in a branched structure. Even more complex polysaccharides may be present if legumes are used in the ration. The main NSP of lupins is a highly complex branched-chain structure containing long ß-(1-4)-D-galactose sidechains attached to a pectin-like mainchain of rhamnose and galacturonic acid linked by ß-(1-4) and α-(1-2) bonds respectively. There are also side chains α-(1-5)-L-arabinose.

Choct and Annison (1990) classified different plants based on their total NSP content from low to high as follows: rice, sorghum, maize, wheat, tritical, rye and barley. Although such a classification goes some way in defining the effect of NSP on diet digestibility it is necessary to further differentiate the types of NSP. The ratio arabinoxylan:ß-glucan is higher in rye and wheat than in barley or oats. Furthermore, while the proportion of soluble arabinoxylans in the total arabinoxylan content may be very low (less than 10%), the soluble ß-glucan to total ß-glucan ratio is high in barley and oats (54 and 80% respectively) (Aman *et al.*, 1989).

Within the same plant species, great variation in NSP content is found according to genotype. From analysis of 22 wheat cultivars, Saulnier *et al.* (1995), quoted by Grosjean and Barrier-Guillot (1996) reported variation of total arabinoxylan, soluble arabinoxylan and relative viscosity ranging from 55.3 to 77.9 g/kg DM, 3.6 to 8.3 g/kg DM and 1.2 to 2.3 respectively. Furthermore, viscosity can be correlated to the soluble arabinoxylan content ($r = 0.78$). The ratio arabinose:xylose and the structure and molecular weight of total arabinoxylan are also influenced by plant genotype (Izidorczyk *et al.*, 1991). Annison (1990) compared the NSP levels and the soluble NSP levels of thirteen wheats obtained from registered seed suppliers across Australia obtained during the 1989-1990 harvest with their determined AME values. It was found that the AME of the wheats correlated inversely with the total water-soluble arabinoxylan ($r = -0.86$, $P<0.001$) and water-soluble NSP levels ($r = -0.91$; $P<0.001$) which suggests that one factor which partially determines the nutritive value of wheat is the level of soluble NSP in the grain. However, NSP analysis is not determined routinely in feed analysis.

Rice bran also contains an appreciable quantity of arabinoxylan similar to that found in wheat and rye. However, whereas the arabinoxylans are of similar structure, those from wheat are much more viscous in solution (Table 1) than the rice bran arabinoxylan which is probably a reflection of their more branched nature. The rice bran arabinoxylan was found to have no anti-nutritive activity when added to sorghum/casein broiler diets which were assayed in a classical AME trial, supporting the conclusions that the viscous nature of polysaccharides plays a role in the anti-nutritive activity (Choct and Annison, 1990). They reported that the AME value of rice bran for broiler chickens was 9.6-10.9 MJ/kg DM.

Table 1. Chemical and physical properties of isolated soluble NSP from wheat and rice bran: molar proportions of the different sugars (Choct and Annison, 1990)

NSP source	Arabinose A	Xylose X	Mannose	Galactose	Glucose	A/X	Viscosity[†] cP
Wheat	0.35	0.60	-	-	0.05	0.58	64
Rice bran	0.40	0.32	0.03	0.17	0.08	1.23	1.6

[†]Viscosity of a 1% (w/v) solution in 0.1M NaCl at 25°C

Gandon (1995) using 30 different barley samples reported wide variation of total β-glucan (30.9 to 55.5 g per kg DM) and soluble arabinoxylan (2.7 to 5.1 g per kg DM) with a relative viscosity of 1.33 to 7.04. However, this variability was clearly not related to the type of barley, 2 *vs* 6 rows, but more to the spring *vs* winter cultivars (Gandon, 1995).

It is difficult to differentiate the effects of geographic location from the ambient conditions such as temperature and humidity. In a comparison of 19 Australian with 12 North American wheat samples there were no consistent differences in their pentosan content which ranged from 5.4 to 7.2 *vs* 5.5 to 6.4% respectively (Wootton *et al.*, 1995). However, in both wheat and barley, dry and hot conditions near maturity tended to increase arabinoxylan or ß-glucan content (Mohammed, 1995). Germination of the grains either before or after harvesting decreased ß-glucan and pentosan content and viscosity due to the activation of endogenous enzymes. Newly harvested wheat is often reported to cause nutritional problems in broilers. Prolonged storage of the grains tends to reduce the ß-glucan content of barley (Brufau *et al.*, 1993). Finally, no effect of sowing period, nitrogen supply or fungus treatment on hemicellulose content of wheat has been reported (Grosjean and Barrier-Guillot, 1996).

NSP and digestion

Two models have been proposed for the antinutritive role of soluble NSP in broiler diets, either that of encapsulation in which the NSP coat inhibits the access of digestive enzymes to the starch, fat and protein and/or the fact that the presence of NSP in the intestinal lumen increases the viscosity of the intestinal contents. As yet the exact anti-nutritive role of NSPs has not been fully identified but it is probable that it involves both these mechanisms.

NSP digestibility: Whilst the microbial population which develops in the crop of poultry is capable of digesting mixed β-glucans, digestion of soluble NSP remains poor. Digestibility of NSP monomers can go from zero to more than 40% depending on their water-solubility (r>0.8) (Carré, 1993). Moreover, digestibility of water-soluble pectins, added at 0.6% of the diet, was shown to be 74% and independent of the age of the birds (Carré, 1993). The caeca appears to be the site of water-soluble NSP digestion via microbial degradation. Caecectomy decreased digestibility of both water soluble pectin (Carré, 1993) and water soluble pentosans (Choct and Annison, 1992b). Recent data has demonstrated that when the levels of NSP in the digesta are high (and viscosity is high) an active microflora is present in the ileum as measured by the levels of short chain fatty acid production (Choct *et al.*, 1995) (Table 2); this may have a detrimental effect on the bird.

Table 2. Effect of NSP on the apparent metabolisable energy (AME, MJ/kg D M) and volatile fatty acid levels (VFA, mmol) in the ileal and caecal contents of broiler chickens

Diet	AME (MJ/kg DM)	Ileal VFA (mmol)	Caecal VFA (mmol)
Control	13.78[a]	8.3[a]	312.3[a]
Control + NSP	10.86[b]	118.2[b]	329.0[a]

a,b: Values marked with different letters are significantly different P<0.05

NSP and the digestibility of other nutrients: Soluble NSP are considered to either block digestion of other important nutrients e.g. protein, fat and starch, or to inhibit absorptive capacity. The exact mechanism of anti-nutritive activity of the NSP has not yet been established. In the case of the digestion of protein, recent studies suggested that the response to elevated NSP is biphasic (Angkanaporn *et al.*, 1994). Guanidated casein was used to investigate the effects of isolated wheat arabinoxylans on endogenous secretions and true protein digestibility. At low concentrations (15 g/kg), the arabinoxylans caused an increase in endogenous amino acid losses whereas at higher concentrations (35 g/kg) a direct inhibition of protein breakdown and amino acid absorption occurred. Whether this inhibition arose from the NSP interacting with the digestive enzymes or the protein substrate is unknown. In the case of starch digestion, there is no indication that the amylase enzymes are inhibited directly by the NSP. Choct *et al.* (1994) measured the activity of amylase enzymes in the digesta of broilers fed a normal wheat (AME 14.52 MJ/kg) and a low AME wheat (AME 12.02 MJ/kg). When related to the level of dry matter there was no difference in amylase activity in digesta suggesting that the wheat NSP was not interacting directly with the amylase enzyme.

NSP and intestinal viscosity: Most of the anti-nutritive activities of NSP which directly affect broiler performance have been attributed directly to soluble polysaccharides. A majority of polysaccharides, when dissolved in water, give viscous solutions. Increases in digesta viscosity associated with wheat arabinoxylan were noted in poultry (Choct and Annison, 1992a). Bedford and Classen (1992) demonstrated that the growth depression caused by substituting high levels of wheat with rye in broiler diets was correlated closely with the viscosity of digesta in the small intestine and resulted in decreased weight gain and feed conversion efficiency. Intestinal viscosity was shown to increase in an exponential manner with the concentration of high molecular weight carbohydrate in the small intestine. White *et al.* (1981) reported that when barley ß-glucan was added to the diet at only 10g/kg, the viscosity of the intestinal contents increased threefold in chickens.

Depolymerisation of polysaccharides decreases the viscosity of their aqueous solutions. In a recent study, Choct and Annison (1992b) compared the anti-nutritive activity of intact and partially depolymerised wheat arabinoxylans. Unlike the intact arabinoxylans, the depolymerised arabinoxylans did not significantly depress the AME of the trial diets (Table 3) and did not increase the viscosity of ileal digesta of the birds to the same extent as intact arabinoxylans.

Table 3. Effect of adding intact and partially depolymerised arabinoxylans (30g/kg) and arabinose and xylose (each 15g/kg) on the AME (MJ/kg DM), starch digestibility, ileal digesta viscosity and live weight gain (LWG, g/week) (Choct and Annison, 1992b)

Diet	AME (MJ/kg DM)	Starch digestibility	Ileal viscosity[†]	LWG (g/week)
Control	16.13[a]	0.98[a]	1.2[a]	430[a]
Intact arabinoxylans (30g/kg)	14.53[b]	0.92[b]	3.0[c]	325[b]
Depolymerised arabinoxylans (30g/kg)	15.74[a]	0.94[b]	2.2[b]	404[a]
Arabinose + xylose (each 15g/kg)	16.23[a]	0.98[a]	1.2[a]	394[a]

[†]Viscosity is expressed relative to the viscosity of water
a,b,c: Values with unlike superscripts differ significantly at $P<0.05$

At present, increases in digesta viscosity should be considered only as a very useful indicator of the action of anti-nutritive NSPs and may be not the mechanism of action. While the exact mechanism of the anti-nutritive effect is thus still unknown, the depression in nutrient digestibility is frequently correlated with digesta viscosity suggesting that viscosity could slow the rate of diffusion of feed substrates, digestive enzymes and their products.

Non-additivity of the effects of NSP: Data indicates that the combinations of fibres in mixed diets do not have the same effect as the sum of the individual components (van Barneveld, 1996). Digestibility of individual amino acids were higher, when combinations of wheat bran and soybean were added to a diet than when the fibre component was supplied by either one of the two constituents indicating that there was an interaction between the two types of fibre.

Exogenous enzymes and NSP utilisation

Exogenous enzymes are used either to supplement an endogenous deficiency or to supply a digestive capacity non-existent in the host animal. It is notable that no nutritional or physiologically harmful effects have been reported from the use of enzyme-addition to feed. The nutritive value of cereals with high levels of soluble NSP can be improved by the use of feed enzymes (Table 4).

Table 4. Effect of a ß-glucanase preparation[†] on the utilization of barley based rations by broilers (7-28 days)

Diet	Weight gain (g)	Food Conversion Ratio	Dietary AME (Kcal/kg)
Barley[††]	842^{a}	1.73	2891^{a}
Barley + Enzyme	887^{b}	1.70	2992^{b}

[†]Rovabio ß-glucanase PF - Rhône Poulenc Animal Nutrition
[††]50% barley
a,b: Values marked with different letters are significantly different P<0.05

Activity of exogenous enzymes: Enzymes need only cleave at a few places in the polysaccharide chain to greatly reduce the viscosity of solutions and thus enhance nutritive value (Table 5). The decrease in intestinal viscosity seems to be dependent on the intrinsic viscosity of the cereal. Using different varieties on wheat plus combinations to achieve a complete range of wheat viscosity values from 1.5 to 3 cP, Barrier-Guillot *et al.* (1995) showed a greater decrease of jejunal viscosity after xylanase suplementation with high-viscosity wheat compared with low-viscosity samples (Table 6). However, the improved AMEn value was similar irrespective of the wheat viscosity.

Table 5. Weight gain, Feed Conversion Ratio (FCR) of broiler chickens (24-31 days) fed wheat or barley diets with or without enzyme[†]: consequences on jejunal viscosity and excreta moisture

Diet	Weight gain (g)	FCR	Jejunal viscosity (cP)	Excreta moisture (%)
Sorghum	378^{ab}	2.07^{bc}	1.8^{c}	59.5^{d}
Wheat	352^{b}	2.21^{b}	10.8^{a}	68.8^{b}
Wheat + Enz 1	392^{a}	1.96^{c}	2.9^{c}	60.7^{d}
Barley	300^{c}	2.53^{a}	3.8^{bc}	75.9^{a}
Barley + Enz 2	390^{b}	2.14^{b}	3.9^{bc}	65.6^{c}

[†]Enz 1: Rovabio xylanase TR; Enz 2: ß-glucanase PF - Rhône Poulenc Animal Nutrition
a,b,c,d: Values with unlike superscripts differ significantly at P<0.05

Table 6. Effect of xylanase supplementation on the feeding value of wheat based diets from different wheat varieties for broilers (Barrier-Guillot *et al.*, 1995)

Cereal	Maize	Wheats							
		Soissons		Mixte		Thesee		Futur	
Viscosity		1.52		1.71		1.90		2.99	
Xylanase	-	-	+	-	+	-	+	-	+
FCR (15-28d)	1.56	1.59	1.55	1.63	1.55	1.64	1.56	1.62	1.56
Jejunal visco (cP)	2.7^{c}	3.2^{c}	3.1^{c}	4.1^{b}	3.2^{c}	4.5^{b}	3.2^{c}	6.6^{a}	3.1^{c}
AMEn (kcal/kg)	3390^{a}	3130^{c}	3280^{b}	3130^{c}	3290^{b}	3120^{c}	3240^{b}	3140^{c}	3250^{b}

a,b,c: Values with unlike superscripts differ significantly at P<0.05

Reduction in intestinal viscosity probably does not explain the total improvement obtained in the utilization of cereals containing NSP. Indeed, presence of NSP increased water content of excreta (Table 5), and NSP-enzymes significantly reduced the excreta moisture. Moreover, Annison (1995) shows that reductions in digesta viscosity associated with enzyme addition were not necessarily matched by falls in NSP content, the measured NSP may increase possibly due to cleavage of nominally insoluble polysaccharide close to the attachment points of the molecule to insoluble parts of the cell wall matrix (Table 7). Studies *in vitro* have demonstrated that, apart from simply cleaving polysaccharides in solution, xylanases can also solubilize arabinoxylans (Gruppen *et al.*, 1993). The increase in the levels of NSP, at the same time as reduction in viscosity indicates that the overall molecular weight of the NSP decreased as a result of the enzyme activity. Reductions in chain length will also effect other physical properties of the NSP such as its surface binding properties.

Table 7. Effects of feed enzyme on AME (MJ/kg DM), soluble NSP and ileal digest a viscosity (mPa.s)

Diet	AME	Soluble NSP	Viscosity
Maize control	16.65^{a}	75.1^{d}	3.16^{b}
Low AME wheat	12.02^{b}	501.0^{ab}	20.28^{a}
Low AME wheat + E	14.95^{a}	594.6^{a}	10.36^{b}
Normal wheat	14.52^{a}	337.5^{c}	9.65^{b}
Normal wheat + E	14.83^{a}	430.5^{b}	5.70^{b}

a,b,c: Values marked with different letters are significantly different P<0.05

It is important to note that the improvement in the AME of cereal diets following enzyme addition is due to improvements in nutrient (starch, protein, fat) digestibility and not due to the availability of NSP itself to act as an energy source for the chicken. In the case of wheat where soluble arabinoxylans are present at levels below 20 g/kg, complete utilisation of this fraction would yield energy in the region of 17 KJ/g which would effectively increase the AME of wheat by 0.34 MJ/kg which is much less than the improvement in AME recorded. Even if complete depolymerisation of the polysaccharide occurs, arabinose and xylose would be released. However, arabinose and xylose mostly passed through the small intestine and were metabolised in the caeca by the microflora, their overall metabolic utlisation was considerably lower compared with hexoses (Schutte, 1991).

The use of enzymes in diets for poultry can have additional benefits to the improved growth of the birds. The main factors influencing ammonia production from litter are the pH and moisture content of the litter, plus environmental temperature. Recent measurements of moisture and N content of litter following the use of enzyme supplementation of diets given to broilers indicated that litter moisture content and N content were lower in the litter of the birds given barley based diets supplemented with β-glucanase (Williams, unpublished data). Measurement of ammonia release from the litter indicated that when a second flock of birds was raised on the same litter, the presence of a β-glucanase in the diet reduced the level of ammonia release by 80%.

NSP-enzyme and diet composition: Previous experiments have shown that the presence of gel-forming nutrients in the diet have a pronounced negative effect through a reduction in fat digestibility (Dänicke *et al.*, 1995). Using wheat-based diets, Schutte *et al.* (1995) compared the effects of fat supplied either as vegetable oil (soya) or animal fats (blended animal fats) on the effect of xylanase. Whilst bird performance and fat digestibility were only slightly enhanced by enzyme supplementation with soya oil based diets, the improvement was significantly greater with diets containing animal fats (Table 8). The magnitude of the effect of enzyme addition was thus dependent on the type of lipid used in the diets.

Table 8. Effect of dietary xylanase in a wheat based broiler diet on performance and digestibility in relation to the fat source (Schutte *et al.*, 1995)

Ingredients	Diet A		Diet B	
Wheat	50		50	
Rye	10		10	
Soya oil	6.5		0.5	
Animal fat	0		6	
Enzyme addition	-	+	-	+
Performance (1-21 d)				
Weight gain	636[a]	638[a]	567[b]	621[a]
FCR	1.61[ab]	1.56[a]	1.75[c]	1.64[b]
Apparent digestibility (%)				
Crude fat	78.3[a]	80.2[a]	60.5[c]	69.9[b]
Amino acids	75.3[ab]	76[a]	73.4[b]	75.3[ab]

a,b,c: Values marked with different letters are significantly different P<0.05

Interactions between NSP-enzymes and feed processing: Until relatively recently the major methods of processing feed employed combinations of heat, pressure and moisture as in pelleting, expansion, anaerobic pasteurisation and extrusion. Many advantages are claimed for feed processing including increased availability of protein and energy, destruction of anti-nutritive factors and hence an extension to the number of raw materials that can be employed in formulations, the ability to include higher proportions of difficult to handle raw materials such as fats and oils and the ability to sterilize feed. The introduction of enzyme treatment in addition to these processes is a factor which merits further attention.

Feed processing can alter the soluble to nonsoluble-NSP ratio. Bedford *et al.* (1991) reported that after pelleting a rye based diet, the content of high molecular weight carbohydrate increased from 4.46 to 5.11 g/l and thus increased ileal viscosity in chicks receiving pelleted feed compared with mash. However, xylanase addition nearly suppressed this effect. In a pelleted diet containing 200 g/kg wheat, the soluble to nonsoluble-NSP ratio was 1:6.8. Following extrusion, the soluble component increased and the ratio was 1:5.9. When the wheat was replaced by barley the ratios were 1:5.7 and 1:5.36 respectively. In each case, the viscosity of the extruded diet was higher than that of the pelleted diet (Vranjes *et al.*, 1994) which could explain the greater decrease of feed intake with barley-based compared with wheat-based diets. In another experiment comparing barley-based diets, Vranjes and Wenk (1995) reported that soluble fibre was higher (36 *vs* 28 g/kg), insoluble fibre lower (163 *vs* 190 g/kg) and total fibre higher (219 *vs* 200 g/kg) in extruded diets compared with unprocessed diets. Extrusion increased extract viscosity (3.7 *vs* 1.3 cP) and water binding capacity (2.2 *vs* 1.6) of the barley. The authors reported that extrusion fragmented and solubilised dietary fibre which resulted in a considerable increase in the viscosity of the whole diet, thus reducing nutrient digestibility and retention in broilers. There was a significant interaction with enzyme treatment. Whilst supplementation with exogenous β-glucanase had very little effect on the untreated barley diet, major increase in most growth and metabolism parameters were recorded with the extruded, enzyme treated diet. The need for supplementary enzymes may thus be higher in diets with processed barley to allow for the increase in the level of soluble fibre and hence potential increase in anti-nutritive activity.

NSP-enzymes and antibiotics: Recent studies have focused on the interaction between addition of NSP-enzyme and antibiotic supplementation and have concluded that the effects were additive. A marked synergism between antibiotic and enzyme was reported (Allen *et al.*, 1996).

NSP-enzyme supplementation, bird age and species: During the first weeks of life of broilers digestive capacity is not fully developed, measured enzymatic activities in the intestine are relatively low and the physiological development of the gastro-intestinal tract is not complete. Indeed, the digestibility of energy estimated by the MEn values of cereals and soybean meals were significantly lower at one and two weeks of age, compared with values obtained at three weeks of age (Mahagna *et al*., 1995). This difference in energy utilization was greater with wheat and soybean meal compared with corn and could be explained by the NSP content of these feedstuffs. Such evolution of digestive capability with age could be expected to influence the response of birds to NSP in the diet and also the response to enzyme supplementation targetted at NSP.

Almirall and Esteve-García (1994) measured the rate of passage through the digestive tract of chicks, of food containing 60% barley. They showed that mean digesta retention time was higher in chicks compared with cockerels (14 *vs* 8 hours) and in the chicks mean digesta retention time was significantly reduced by the addition of β-glucanase in the diet (11.5 *vs* 14 hours). The increase of dietary MEn content following NSP-enzyme supplementation was greater in 3 to 4 wk old broilers compared with adult roosters (Smulikowska, 1995) or laying hens (Huyghebaert and De Groote, 1995). These results tend to support the viscosity theory and suggest that the young bird is more affected by the effects of viscosity and that the young chick will respond most to treatments which reduce the adverse effects of NSP.

Few experiments have considered the effects of NSP-enzyme supplementation in species other than *Gallus*. Cowan and Hastrup (1995) recently reported a significant improvement of 5.2% in growth up to 11 weeks of age in ducks, and by 3% up to 20 weeks of age in turkeys. Feed conversion efficiency was enhanced by 6% in turkeys.

Conclusions

The recognition of the anti-nutritional properties of NSP in cereals has permitted major advances to be made in the formulation of diets for poultry and pigs. It is now possible to account for some of the variability found in the energy value of cereals and to prevent nutritional disorders associated with high levels of NSP in poultry diets. Knowledge of the chemical structure of NSP has permitted the development of enzyme technology to overcome the adverse effects. For the feed producer, the use of enzymes offers both economic benefits in the ability to choose the best 'value for money cereals', the opportunity to include newly harvested grains which are recognised to contain high levels of NSP without quantitative limits, the ability to upgrade the nutritive value of cereals and increased flexibility in the choice of feed materials. For the poultry producer there is the opportunity of more efficient feed conversion, heavier birds or reduced rearing period, better litter conditions, improved environmental control, improved health and hygiene in the flock and a reduction in the number of carcasses rejected at the processor.

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